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Nonlinear compression of tilted light pulses

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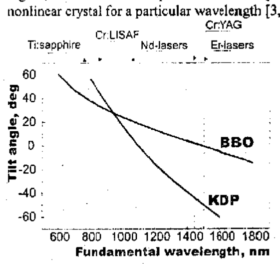
Summary
Nonlinear pulse compression under special conditions of large group-velocity mismatch (GVM) and strong energy exchange suggested for the first time 8 years ago [1,2], was demonstrated to be a simple and efficient method to generate powerful femtosecond pulses via frequency doubling of picosecond Nd-laser pulses in KDP crystal. However, the direct transfer of this technique to other wavelengths or other well-developed laser sources (Ti:sapphire, for instance) encounters serious problems related to the lack of nonlinear crystals with suitable dispersive properties. To this regard, the use of tilted pulses offers unique possibility to adjust the GVM in a nonlinear crystal for a particular wavelength [3,4].



In this Contribution we present the experimental results on second-harmonic pulse (at 527.5 nm) compression in BBO and third-harmonic pulse (at 351.7 nm) compression in KDP crystal. In case of type II BBO the tilt angle was calculated to introduce symmetrical GVM of the incident e and o polarized pulses in respect to the second-harmonic one. In type I KDP the GVM between the incident pulses was provided by dispersion whereas the pulse tilting ensured sum-frequency to have the GV equal to the average of the incident ones. A combination of telescopes and gratings was used to tilt the incident pulses as well as to restore the front of the output pulses. In both cases compressed pulses with durations well below 200 fs (what corresponds to ~9-fold compression factor) were measured. The simulation shows that proper GVM conditions can be found for a variety of wavelengths (Fig.1).

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Measurement and calculation of the critical pulsewidth for gain saturation in semiconductor optical amplifiers

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Active semiconductor optical waveguides are essential components in many recently proposed devices for high-speed optical signal processing. It is well known that ultrafast carrier dynamics, like carrier heating and spectral holeburning, lead to gain non-linearities, which restrict the modulation bandwidth of semiconductor lasers. In the case of pulse amplification, these non-linearities lead to a pulsewidth dependence of the gain saturation [1]. A critical pulsewidth can be defined [2], which separates two qualitatively different regimes: a long-pulse regime, where the gain is determined by the pulse energy only, and a short-pulse regime, where the gain also depends on the pulsewidth. Calculated critical pulsewidths are on the order of several picoseconds [1], which is getting in the range of pulses being explored for ultrafast optical signal processing. Experiments that we are aware of, however, do not investigate the detailed dependence of the saturation energy versus pulse duration, and subsequently do not allow extraction of the critical pulsewidth.

We have measured the gain saturation of a 250 μm-long InGaAsP optical amplifier operating at 1.55μm, for pulse durations from 200 fs to 10 ps. Infrared pulses of 200fs are generated using the idler of an optical parametric amplifier. Longer pulsewidths and linear chirp compensation are achieved using a pulse-shaper in the beam path. Cross correlation measurements show that the pulses are background-free.

The measured amplifier gain as a function of output energy (in the range from 5 fJ to 5 pJ) clearly shows that the onset of gain saturation is pulsewidth dependent. By plotting the corresponding 3dB output energy as a function of the pulse duration we deduce a critical pulsewidth, for which the saturation induced by depletion of the carrier density (sometimes denoted linear gain saturation) equals the saturation due to ultrafast carrier dynamics. We obtain critical pulsewidths in the range from 2 to 7 ps, depending on the optical wavelength and bias current. Note that these values are significantly larger than the relaxation time of the carrier plasma temperature ($\tau_T \approx 700$ fs). However, as the pulsewidth becomes comparable to and shorter than τ_T, the variation of saturation energy with pulsewidth changes qualitatively, depending on whether the main saturation mechanism comes from spectral holeburning or carrier heating. In agreement with calculations based on density matrix equations [2], we find a larger role of carrier heating at shorter wavelengths.

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